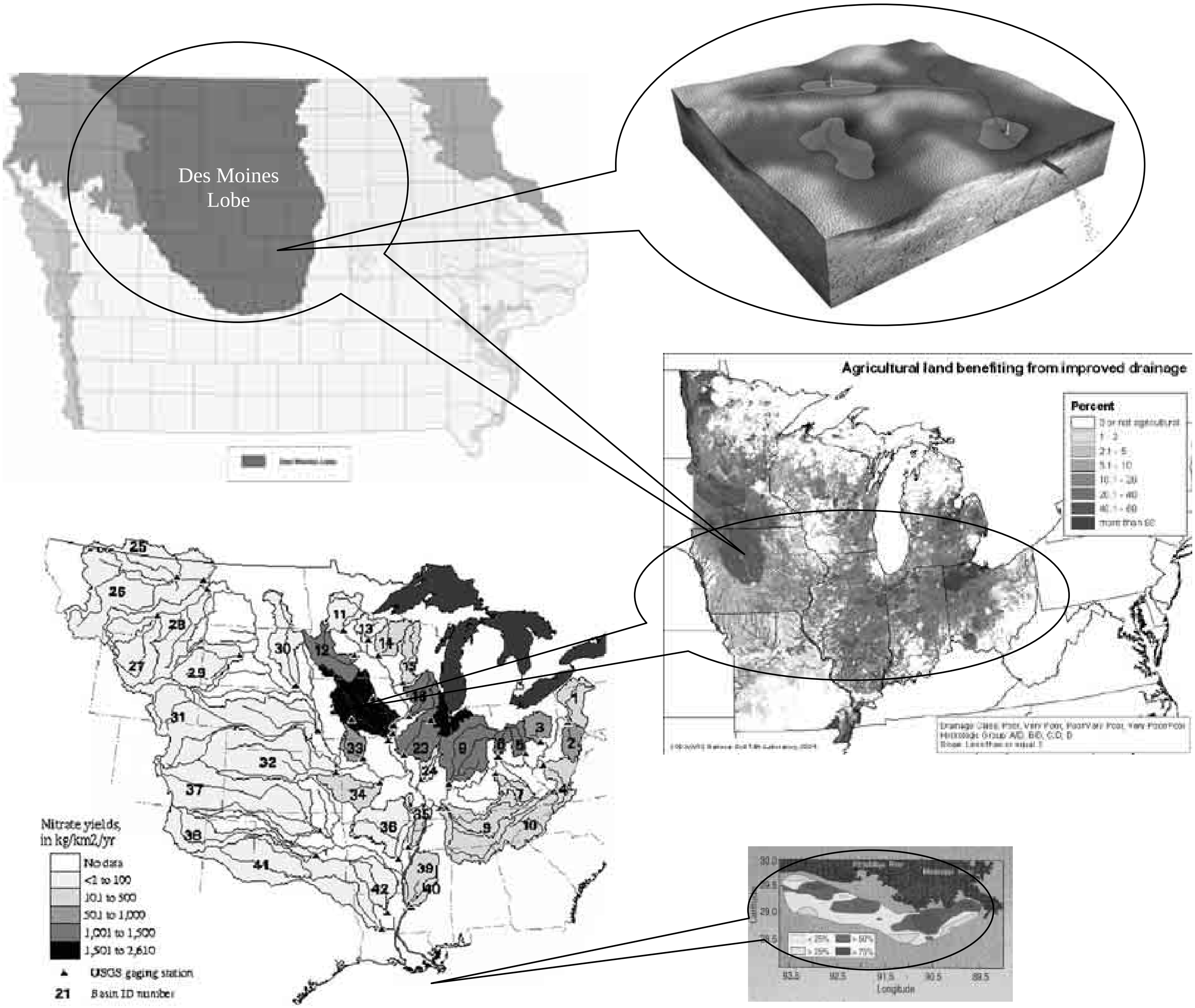
Integrated Drainage-Wetland Systems for Reducing Nitrate Loads from Des Moines Lobe Watersheds

(An Innovative, Targeted Strategy for Addressing Contributions to Hypoxia from Tile-Drained Watersheds in the Mississippi River Basin)

HUC Watershed # 07100002



A Cooperative Proposal by
the Iowa Department of Agriculture and Land Stewardship and Iowa State University

Dean W. Lemke, P.E.
Chief, Water Resource Bureau
Division of Soil Conservation
Iowa Department of Agriculture and Land Stewardship
Wallace Building, Des Moines, IA 50319
(515) 281-3963
dean.lemke@idals.state.ia.us

IOWA STATE UNIVERSITY

Nitrate (NO_3) transported to the Gulf of Mexico is believed to increase hypoxia. Although some mismanagement/over-use of fertilizer and manure nitrogen (N) causes part of the problem, the major causes are the hydrological and land-use changes (from prairies/marshes to row-crops) that came with subsurface drainage. Therefore, the best real hope for a permanent solution involves “structural modifications” of the drainage systems. The approach taken in this project will be to gather information to use with improved crop-growth, hydrologic, and wetland models to develop integrated systems to optimize nitrate (NO_3) load reduction at the watershed scale. The concept being tested/demonstrated is the integration of nitrate-removal wetlands, as a proven technology, with emerging technologies for controlled drainage/shallow drainage to achieve a systems approach. Results for specific watersheds will be used to develop an optimum drainage system design that can be implemented, then monitored for performance. Assessment, in terms of physical, technical, and economic performance, can then be conducted for extension to other areas.

Overview/Synopsis

- The Problem: nitrate (NO_3) leached from extensive areas of drained cropland in the Corn Belt and transported down the Mississippi River causes hypoxic conditions in` the Gulf of Mexico (plus local drinking water quality concerns).
- Major Causes: hydrological and land-use changes accompanying extensive subsurface drainage of the Corn Belt (25% of Iowa is drained) make more NO_3 available for leaching and enhance transport with quicker/short-circuited and greater volumes of drainage.
- Economic/Environmental Considerations: subsurface drainage creates very productive croplands and reduces other water quality concerns including sediment, ammonium-nitrogen, phosphorus, pesticides, and micro-organisms; therefore, this land should be kept in production by solving the nitrate (NO_3) transport problem.
- Solution: although some improvement could be made by better management of nitrogen (N) inputs, the best hope for a significant, permanent reduction in NO_3 transport is through structural modifications of the subsurface drainage systems that could have both water quality and crop production benefits.
- Approach: use actual soils, topography, and weather data with improved crop growth, hydrologic, and wetland models to design integrated wetlands and controlled/shallow drainage systems optimized to reduce NO_3 loading while maintaining or improving crop performance. Develop the optimum drainage-wetland system design for specific study areas with landowner cooperation, install it, and monitor its water quality performance.
- Extension: do outreach to publicize the study to stakeholders and policy makers; and do a feasibility assessment, in terms of physical, technical, and economic parameters, for possible extension to other areas in Iowa and beyond.

Watershed Planning Efforts

The problem of hypoxia associated with NO_3 leaching and transport down the Mississippi River to the Gulf of Mexico has been a topic of regional, statewide, and local meetings in the Des Moines Lobe. Regional meetings such as the Monitoring, Modeling, and Research Workshop held in St. Louis in October last year have identified the need to address questions such as “What is the spatial distribution of nutrient yields in the Mississippi River and what are the areas of highest nutrient yields,” and “What natural and anthropogenic factors affect spatial and temporal changes in nutrient yields” in generating solutions to the hypoxia problem.

Statewide, the fact that Iowa is one of the leading states as a source of NO_3 to the Gulf was one of the motivating factors for the Iowa Water Summit held on the Iowa State University (ISU) campus November 24, 2003. At that meeting, three of the five work groups, “Nonpoint Sources,” “Nutrients,” and “Impaired Waters Restoration,” identified the need for feasibility assessment and demonstration of hydrologic modifications as a new way of addressing nonpoint source water quality concerns, particularly NO_3 leaching.

On a more local basis, the boards of trustees of Iowa’s 3000 drainage districts have at their annual meetings for the past three years reviewed and discussed the concerns with transport of NO_3 through artificial drainage systems and the resulting effects upon Gulf hypoxia. Through their Iowa Drainage District Association (IDDA), an active strategy has been developed to begin addressing these concerns through several efforts to support, advise, and assist the implementation of NO_3-removal wetland technologies being implemented in Iowa through the Iowa Conservation Reserve Enhancement Program (CREP). More recently, the IDDA has tendered agreement to partner and collaborate with this project by providing the necessary linkage to and networking with drainage districts, boards of trustees, and affected landowners.

Through this linkage, a watershed study site search was initiated for this project, and three watersheds have received approval of the governing boards of trustees of the three drainage districts. These approvals provide ingress/egress for needed land surveys, engineering and design needed to conduct the project. The boards of trustees have also committed to working with the landowners of their districts to call informational meetings and to facilitate landowner input and local decisions.

Watershed Background/Description

The main subject area for this project is the Des Moines Lobe in north-central Iowa drained mostly by the Des Moines, Raccoon, Iowa, and Skunk Rivers. The reason for this choice is that much of the relatively flat, poorly-drained land in Iowa requiring systematic artificial subsurface drainage is in this most recently glaciated, “prairie-pothole” region. With artificial drainage, this land became some of the most valuable, productive land in the State. In 2002, the average land value for the 22-county area making up most of the Lobe was $2,436 an acre, and 80.5% of that area was in row-crops (42.9% in corn and 37.6% soybeans). However, this drained land also has become a source of significant NO_3 loss because of the changes in land-use and hydrology brought about by “tile drainage.” In wet 1993, it was estimated that 25% of the NO_3 entering the Gulf of Mexico with flow from the Mississippi River was from Iowa.

While surface runoff is decreased with subsurface drainage (resulting in decreased losses of sediment, ammonium-nitrogen, phosphorus, pesticides and micro-organisms), subsurface flow and leaching losses of NO_3 are increased. This is due mostly to an increase in volume and the “short-circuiting” of subsurface flow, but also in part to the increased aeration of organic-rich soils with potentially increased mineralization and formation of NO_3 (and less denitrification) in the soil profile. While studies have shown that improved N management practices, in the way of correct rate, timing, and placement, have some potential to reduce NO_3 leaching, that potential is probably limited to 25% or less. Reduced tillage has the potential for additional reduction, but again limited in magnitude. Although alternate cropping, such as small grains, alfalfa, or other sod-based crops/rotations, can cause a major reduction, currently they also have major economic implications.

A permanent solution to the environmental problem of hypoxia in the Gulf of Mexico will require more than improved N management and tillage practices. We propose a systems approach, integrating NO_3-removal wetlands, as a proven technology, with the emerging technologies of drainage modification. Iowa State University studies of Iowa CREP wetlands demonstrate that relatively small areas of wetlands intercepting tile drainage can remove up to 70% of the NO_3 in tile drainage water. For this project, NO_3-removal wetlands would be integrated with drainage system modifications, decreasing the volume of subsurface drainage while increasing the potential number and effectiveness of the wetlands. The drainage system modifications considered will be controlled drainage, where a control structure is used to maintain the water table at a shallower depth during certain times of the year, and shallow drainage, where tile drains are placed at 24-30 inches rather than 48-60 inches to control the water table at a shallower depth. Studies at the University of Illinois, University of Minnesota, and North Carolina State University have found that controlled drainage and shallow drainage can reduce subsurface flow and NO_3 export by 25 to 45%. The integration of shallow and controlled drainage systems with NO_3-removal wetlands has the potential to simultaneously decrease the volume of subsurface drainage, increase the number of wetland sites, push those sites closer to the NO_3 source, and enhance wetland performance by increasing the average residence time in the wetlands.

The integration of these approaches also provides opportunities for developing market-based solutions. Private and public interests coincide if we are able to couple increased water-use efficiency and crop yield due to drainage modification with improved water quality due to integrating drainage and wetland systems. This opens an array of possible strategies for leveraging funds, capabilities and activities of private and public sources.

Project Activities

The specific subwatersheds in the Des Moines Lobe that are the focus of this proposal are three drainage districts (DD) in Palo Alto and Pocahontas counties. Palo Alto DD12 is an approximately 2000-acre watershed having desirable topography and extensive existing elevation and location survey of subsurface tile lines. Palo Alto DD80 and Pocahontas and Palo Alto Joint DD77 comprise approximately 123,000 acres in total. Aerial land survey using LiDAR will be conducted at drainage district expense of an estimated $125,000. The survey will generate digital elevation data accurate to 15 cm with 95% confidence, and coupled with approval by the respective boards of trustees of this 123,000 acres provides an invaluable resource to accomplish this project. It allows broad scale assessment to identify specific drainage areas having topography typical of the Des Moines Lobe as well as provides flexibility in selection of suitable sites of 1000-5000 acres each. The project would proceed in three phases, (1) determining the preferred drainage system design, (2) developing site-specific design plans, and (3) construction and performance monitoring of the preferred system. Monitoring established prior to drainage system modifications will be continued post-construction to monitor the impacts of system modifications. Monitoring sites will be instrumented for automated sample collection and continuous flow measurement so that total flow and nitrate mass transport can be calculated. Pre-construction monitoring would occur at the tile outlet for the drainage districts being studied. Post-construction monitoring would occur at the tile outlet above the NO_3-removal wetlands and at the outlets of the wetlands.

Modeling to predict performance and determine the preferred design will be done in years 1 and 2, with engineering design, landowner decisions and construction in year 3. Background monitoring will begin in year 1 and continue throughout the project. Post-construction monitoring and regional assessments will be conducted in years 3 through 5, using paired watersheds as needed.

Phase 1 - Determination of Preferred Alternative Drainage System

In order to evaluate the effects of combined drainage modifications and NO_3-removal wetlands, the outflow from the drainage system must be computed. Modeling the hydrologic system on a field-scale provides the opportunity to evaluate alternative drainage systems in order to develop recommendations on the types of modifications that could be made as well as estimate the potential for these systems to reduce NO_3 movement from agricultural landscapes. To evaluate the impact of the drainage modifications in our systems approach, the effects on drainage outflow and crop response must be considered along with the performance of NO_3-removal wetlands. This will involve simultaneously modeling crop growth and site hydrology and then outputting daily loading to NO_3-removal wetlands over 30 years of weather records for each drainage design option. The modeling objectives are to identify combined drainage-wetland systems with the greatest potential for reducing NO_3 export from subsurface drainage while maintaining or increasing crop production. Preferred alternative drainage systems will be selected based on the guiding principle of reducing water and NO_3 flow out of the entire system, which includes the field drainage and wetlands, when compared to a conventional system with existing tile drainage conditions (deeper tile) and without NO_3-removal wetlands. We will also estimate the economic impact on crop yield, which will be essential in developing market-based approaches.

Phase 2 - Drainage System Design for Implementation

After identifying the preferred alternative drainage scenarios, engineering design and additional surveying needed to implement the preferred alternative drainage systems will be performed by drainage engineers. Processes used in selection and oversight of the engineering design firm will mirror those of the other programs administered by the Iowa Department of Agriculture and Land Stewardship (IDALS). At the end of the surveying and engineering design phase, construction plans and specifications as well as cost estimates will be prepared. These results will be the basis for assessments for extending these practices across the intensively-drained Des Moines Lobe.

Phase 3 – Construction, Performance Monitoring, and Regional Assessments

Upon completion of the designs in the study watersheds, additional local meetings with the study area landowners and their boards of trustees of the three drainage districts will be held to consider construction of the designs. Project funds will be used to cost-share 75% of the cost of construction using procedures of other programs administered by IDALS, with the potential for additional state cost-share to further reduce landowner costs. Decision to proceed to Phase 3 of the project and construct the designs is held by the landowners and their drainage district boards of trustees. Preference will be given to cost-sharing construction in the study watersheds but if not possible, the cost-share funds will be offered to other lands and landowners within DD12, DD80, and DD77. In that case, the Phase 2 design results and cost estimates will serve as a basis to facilitate local decision making in other sub-drainage areas, followed by further site specific design to develop construction plans. The constructed drainage and wetland systems will be monitored for performance, through water quality sampling to demonstrate NO_3 and hydrologic reductions, and measurement of production impacts including crop yields to demonstrate any enhanced economic returns for driving future market-based implementation of the practices. During the monitoring period, the Phase 2 designs and cost estimates will also be used for quantifying extension of the technology and practices across the Des Moines Lobe.

Outreach Activities

Outreach will be a critical, yet challenging step because the project seeks to evaluate and demonstrate emerging technologies. Producers will be concerned that practices do not result in crop loss due to surface water ponding, nor machines mired in wet soils at planting and harvest times. Outreach will address the fact that producers are not familiar with these technologies and that the approaches (i.e., keeping water tables high and retaining water in wetlands) run diametrically opposite of the longstanding approaches of draining excess water away as rapidly as possible. Outreach will also be targeted to address the economic concerns of producers, to capitalize on the potential for these technologies to enhance profitability, and to set the stage for future implementation to be driven by market-based forces.

IDDA and ISU Extension will assist in the outreach effort. Additionally, other groups such as Iowa farm and commodity organizations have agreed to participate on an outreach committee that meets regularly throughout the project life. That committee will foster outreach through the variety of media mechanisms available through these organizations, with a goal to achieve delivery of consistent messages. Outreach will be directed to landowners, drainage district trustees, farm media, downstream water users and the general public, as well as policy makers at the local, state, and national levels. Messages of the outreach efforts will vary as the project progresses to provide the latest information available. Targeted outreach will especially be the focus within the three study areas and the larger three drainage districts, with periodic landowner meetings held within the study areas to assure they are the first to receive current information from the project studies. Consideration by the affected landowners within the project study to construct the preferred alternative drainage alternatives will ultimately "test the waters" as a measure of the future outreach, education, and technology transfer efforts that will be needed to foster and achieve broad scale adoption of the technology across the Des Moines Lobe.

Project Team

The project team is the same team that developed the nitrate-removal wetland technologies of the Iowa CREP, with addition of two members having specialized expertise in modeling needed for this project. This interdisciplinary team uses systems approaches to integrate the work of scientists and engineers working on water quality issues in agricultural watersheds including nitrogen management, tillage practices, vegetative filters, wetland restoration, and drainage water management.

Name	Title/Role	Qualifications
Dean W. Lemke, P.E.	Chief of the Water Resources Bureau, Iowa Department of Agriculture and Land Stewardship	• 32 years experience in public programs related to environmental concerns from agricultural production • Project contract officer for Agricultural Drainage Well Research and Demonstration project • Administrator of Iowa CREP • Member of Coordinating Committee of Mississippi River/Gulf of Mexico Watershed Nutrients Task Force
James L. Baker, Ph.D.	Professor, Department of Agricultural and Biosystems Engineering, ISU	• 37 years experience at Iowa State University • Research focus on nonpoint source water pollution • Investigated effects on water quality of off-site practices involving permanent vegetation/buffers, wetlands, and drainage water management • Worked with farm management practices and equipment (e.g., a new fertilizer applicator) that result in protection of our soil resource against erosion, efficient use of agricultural chemicals and energy resources, and improved water quality of agricultural drainage

William G. Crumpton, Ph.D.	Associate Professor, Department of Ecology, Evolution, and Organismal Biology, ISU	• 22 years experience at Iowa State University • Current research focus on water quality functions of wetlands in agricultural watersheds • Work provided much of the research foundation for the Iowa CREP, a ten-year $89 million program using targeted wetland restorations to reduce nitrate loads from tile-drained agricultural watersheds • Currently chairs the undergraduate Environmental Science undergraduate program and the Water Resources graduate major at Iowa State University.
Stewart Melvin, Ph.D.	Professor, Department of Agricultural and Biosystems Engineering, ISU	• 40 years experience with 32 years as Extension Agricultural Engineer and 8 years as Department head • Experienced in drainage, soil and water management • Research in animal waste, soil compaction, agricultural practices on drainage water quality, along with controlled drainage and subirrigation • Interim director of the Iowa State Water Resources Research Institute, and co-principal investigator of the Agricultural Drainage Well Research and Demonstration Project
Bill Batchelor, Ph.D.	Associate Professor, Department of Agricultural and Biosystems Engineering, ISU	• 10 years experience at Iowa State University • Involved in development and implementation of process-oriented crop growth models • Worked with CROPGRO (generic legume growth model) and CERES (generic cereal growth model) since 1986 and a leader in developing methods to use crop growth models to address complex environmental problems facing producers and society
Matthew J. Helmers, Ph.D.	Assistant Professor, Department of Agricultural and Biosystems Engineering, ISU	• Experience in hydrologic modeling and characterization of soil hydraulic properties • Research on performance of in-place vegetative filters including hydrologic modeling and monitoring • Experience as an engineering consultant

Table 1. BUDGET INFORMATION - EPA Watershed Initiative Grant Program[1]

SECTION A - BUDGET SUMMARY			
Watershed Project, Activity or Work Plan Element	Federal	Non-Federal	Total
1. DD 77	$552,078	$258,421	$810,499
2. DD 80	$483,068	$226,118	$709,186
3. DD12	$345,049	$161,513	$506,562
4.			
Totals	$1,380,195	$646,052	$2,026,247

SECTION B - BUDGET CATEGORIES					
	Watershed Project, Activity or Work Plan Element				Total
Budget Categories	(1)	(2)	(3)	(4)	
a. Personnel	$217,820	$190,593	$136,138	$	$544,551
b. Fringe Benefits	$64,402	$56,352	$40,251		$161,005
c. Travel	$12,000	$10,500	$7,500		$30,000
d. Equipment	$24,000	$21,000	$15,000		$60,000
e. Supplies	$26,000	$22,750	$16,250		$65,000
f. Contractual					
g. Construction	$200,000	$175,000	$125,000		$500,000
h. Other					
i. Total Direct Charges (sum line a-h)	$544,222	$476,195	$340,139		$1,360,556
j. Indirect Charges	$7,855	$6,873	$4,910		$19,638
TOTALS (sum line i-j)	$552,078	$483,068	$345,049	$	$1,380,195

[1] Excerpted from Standard Form 424A, OMB Circular A-102